Validation of Nonspherical Ice Particle Models for Precipitation Remote Sensing

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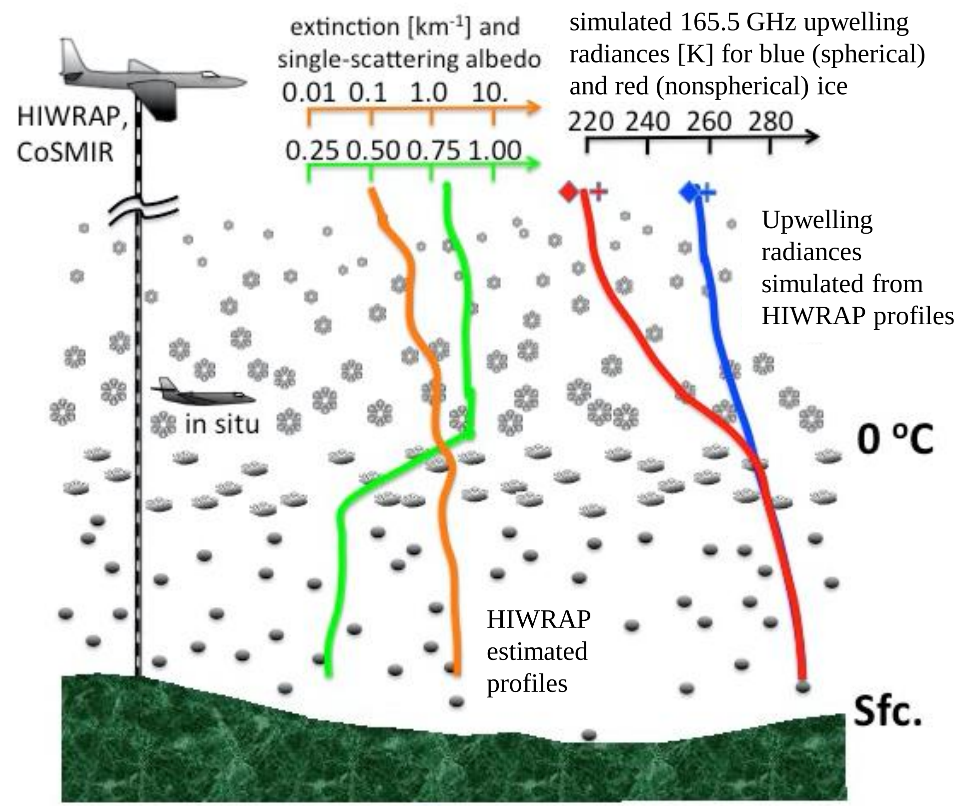
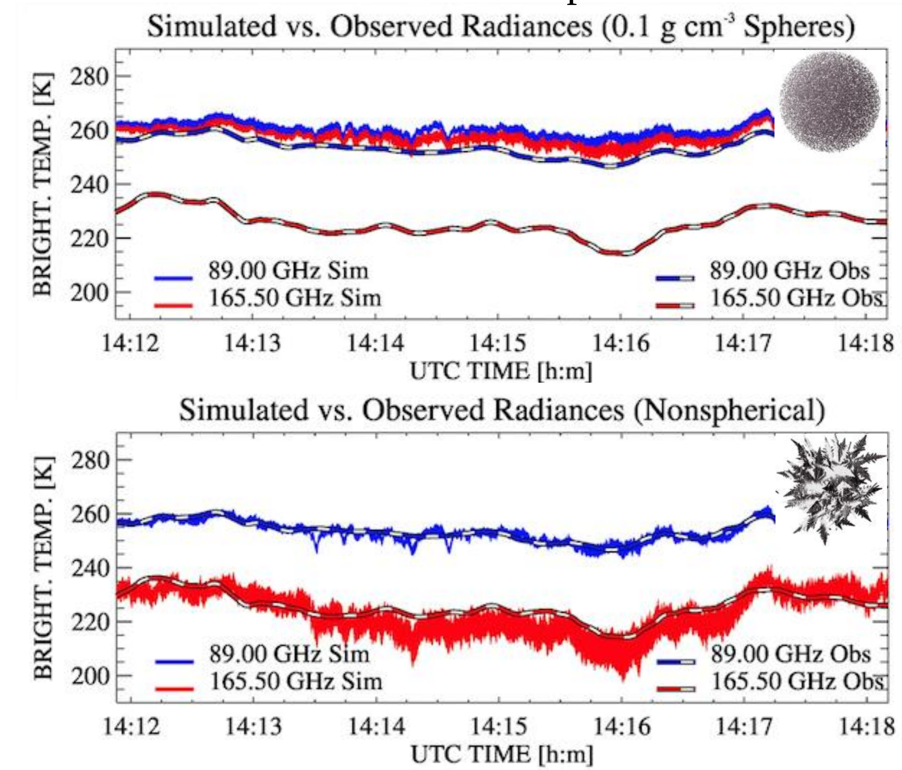


CoSMIR Comparison



The objective is to determine how well different snow particle models can be used to simultaneously explain radar and radiometer observations from GPM-like instruments. The airborne Ku/Ka band radar (HIWRAP) estimates a precipitation vertical profile, which is then used to simulate radiances at 89 and 166 GHz. Upwelling radiances are most sensitive to the properties of the snow layer (see radiance vertical profiles at above left). The nonspherical particles modeled in this study produce radiances in much better agreement with CoSMIR observations, compared to traditional spherical particles (above right).

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References:

William S. Olson, Lin Tian, Mircea Grecu, Kwo-Sen Kuo, Benjamin T. Johnson, Andrew J. Heymsfield, Aaron Bansemer, Gerald M. Heymsfield, James R. Wang, and Robert Meneghini, 2016: The Microwave Radiative Properties of Falling Snow Derived from Nonspherical Ice Particle Models. Part II: Initial Testing Using Radar, Radiometer, and In Situ Observations. *Journal of Applied Meteorology and Climatology*, **55**, 709-722.

Kwo-Sen Kuo, William S. Olson, Benjamin T. Johnson, Mircea Grecu, Lin Tian, Thomas L. Clune, Bruce H. van Aartsen, Andrew J. Heymsfield, Liang Liao, and Robert Meneghini, 2016: The Microwave Radiative Properties of Falling Snow Derived from Nonspherical Ice Particle Models. Part I: An Extensive Database of Simulated Pristine Crystals and Aggregate Particles, and Their Scattering Properties. *Journal of Applied Meteorology and Climatology*, **55**, 691-708.

Gerald M. Heymsfield, Lin Tian, Lihua Li, Matthew McLinden, and Jaime I. Cervantes, 2013: Airborne Radar Observations of Severe Hailstorms: Implications for Future Spaceborne Radar. *Journal of Applied Meteorology and Climatology*, **52**, 1851-1867.

James R. Wang, Gail M. Skofronick-Jackson, Mathew R. Schwaller, Carey M. Johnson, William B. Monosmith, and Zhaonan Zhang, 2013: Observations of Storm Signatures by the Recently Modified Conical Scanning Millimeter-wave Imaging Radiometer. *IEEE Trans. Geoscience Remote Sensing*, **51**, 411-424.

Data Sources:

Figure depicting estimates of precipitation properties is derived from observations of the High-altitude Wind and Rain Airborne Profiler (HIWRAP) radar; see Heymsfield et al. (2013). Observed microwave radiances at 89 and 166 GHz shown in the figures are derived from the Conical Scanning Millimeter-wave Imaging Radiometer (CoSMIR); see Wang et al. (2013). Both sets of data were taken on flights of the NASA ER-2 aircraft on 20 May 2011, during the Midlatitude Continental Convective Clouds Experiment near the Kansas/Oklahoma border.

Technical Description of Figures:

Left Figure: schematic of the field observations for testing the ice particle scattering models, including airborne HIWRAP and CoSMIR nadir-view observations from the NASA ER-2 aircraft. Orange and green curves are typical profiles of precipitation extinction and single-scattering albedo, respectively, at 166 GHz. Blue and red curves are the corresponding upwelling radiances at 166 GHz for spherical and nonspherical ice particle models, respectively. Particle models are described in Kuo et al. (2016). Right Figure: microwave radiances at 89 GHz (solid blue) and 166 GHz (solid red) simulated from the estimated precipitation profiles from HIWRAP, using spherical (upper panel) and nonspherical (lower panel) ice particle models. Width of curves indicates uncertainties due to humidity and precipitation size distribution variability. CoSMIR-observed radiances at 89 GHz (dashed blue) and 166 GHz (dashed red) are shown for comparison.

Scientific significance, societal relevance, and relationships to future missions:

At higher latitudes (greater than 40 ^{o}N or less than 40 ^{o} S), snow contributes a significant proportion of the net precipitation at the earth's surface, making it an important component of the global water cycle and a key climate indicator at those latitudes. The responses of the Ku/Ka band radar and multichannel microwave radiometer of the Global Precipitation Measurement mission to snow particles must be properly modeled so that GPM measurements can be used to accurately quantify snowfall rates. In this study, the scattering properties of snow particle models are evaluated using field campaign measurements from airborne HIWRAP and CoSMIR observations. Nonspherical snow models produce simulated radiances at 89 and 166 GHz that are consistent with CoSMIR observations, while simpler, spherical snow particle models do not. The proper interpretation of the higher-frequency microwave channel data from GPM, as well as other microwave sensors such as SSMIS and AMSR2, therefore depends on models of the atmosphere containing nonspherical snow particles. Proposed satellite missions such as ACE and CaPPM will utilize higher-frequency radar and passive microwave channels to interpret cloud and precipitation distributions, and so further research on the properties of snow particles will be needed to better quantify their impact on remote-sensing observations.

Diurnal Cycle and Evolution of Tracked Cold Cloud Clusters

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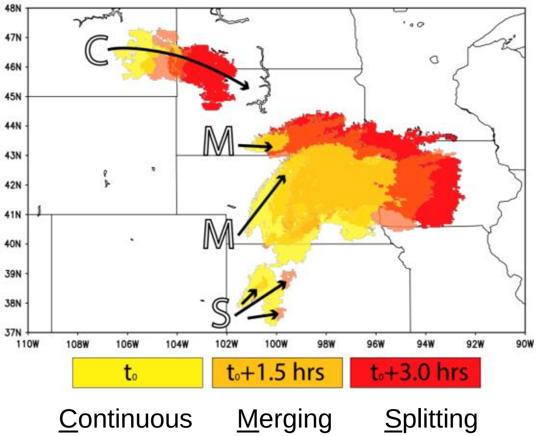
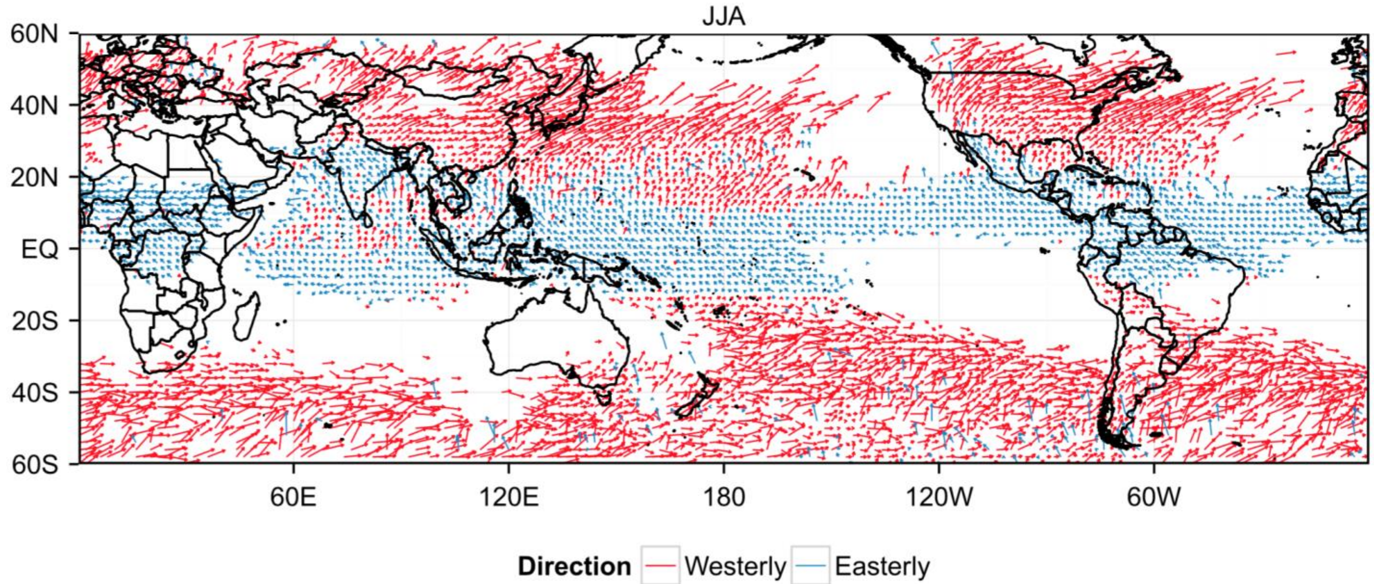
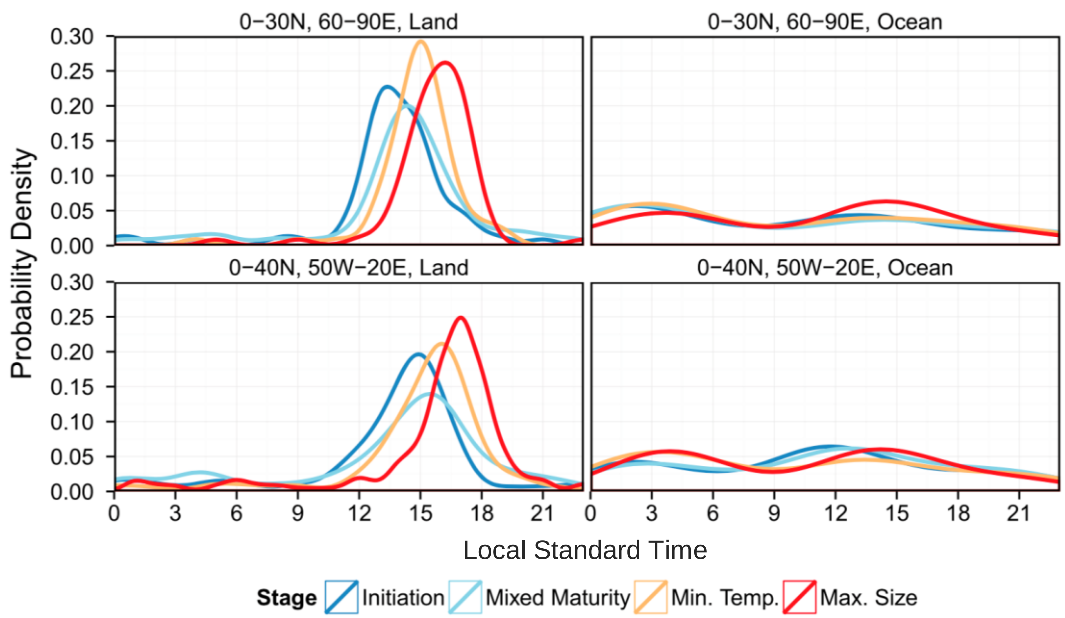




Tracking clouds using overlapping clusters between satellite images (top left) allows scientists to study their trajectories (top right). By analyzing millions of clouds in this manner, we can determine the time of day that major storm phases occur (bottom).



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References:

Esmaili, R. B., Y. Tian, D. A. Vila, and K.-M. Kim. 2016. "A Lagrangian analysis of cold cloud clusters and their life cycles with satellite observations." Journal of Geophysical Research - Atmospheres, 10.1002/2016JD025653

Data Sources:

NCEP/CPC 4-km, half hourly infrared (IR) brightness temperature dataset
Integrated Multi-satellitE Retrievals for GPM (IMERG), the next-generation, Global Precipitation Measurement era product suite

Technical Description of Figures:

Graphic 1 (top left): Schematic of area overlap handling of continuous systems (c), merging systems (m), and splitting systems (s). The image was taken of thunderstorms developing over the American Midwest beginning at 3:00 pm EST on 30 June 2012 using cloud brightness temperature observations. Yellow represents the initial time, orange 1.5 hours later, and red 3.0 hours after initial detection.

Graphic 2 (top right): Climatology of cloud cluster trajectories in January-August, 2002-2012 with 6-9 hour lifetimes binned at 2° x 2°. Lines show average displacement of all cloud clusters that initiated at the same point over the 11-year period studied. Coloring indicates net zonal movement of clusters. Grid boxes with fewer than five initiations were not displayed.

Graphic 3 (bottom): Probability of certain cloud life cycle phases occurring at a particular local standard time in two regions, 0°–30°N and 60°–90°E (India) and 0°–40°N, 50°W–20°E (West Africa). Long-lived clusters achieve minimum temperature and maximum extent at different times, which occur simultaneously in short-lived clusters. Mixed maturity is defined as the simultaneous occurrence of minimum temperature and maximum size.

Scientific significance, societal relevance, and relationships to future missions: Storms are a major contributor to natural hazards, so understanding how and when cloud development occurs is important for storm prediction. Our results show that during their life cycle, cloud clusters typically undergo distinct life cycle stages. However, the clusters with longer and shorter lifetimes mature differently: Long-lasting clusters tend to achieve their temperature maturity before size maturity, thereby prolonging this stage. Timing wise, afternoon development is more likely over land, while over the ocean there are two peaks in activity, one in the early morning and one in the afternoon. This study provides the first big picture survey of cold cloud cluster evolution, characteristics, and daily cycle.

NASA Satellites Track Air Pollution from Sulfur Fires in Iraq

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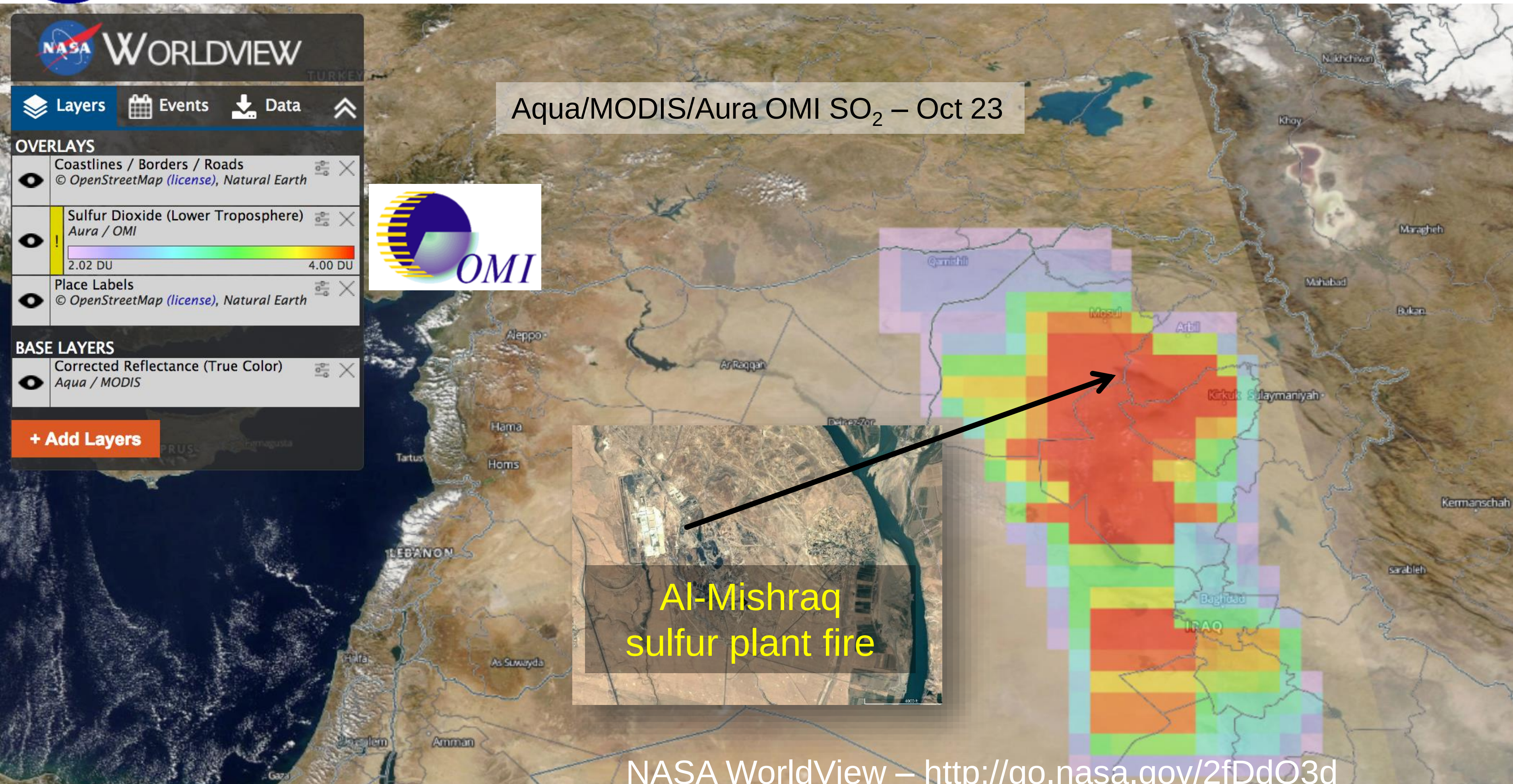

The Sulfur Dioxide (SO_2) data, produced by the the Dutch-Finnish Ozone Monitoring Instrument (OMI) on board NASA's Aura satellite are ingested within three hours into NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) platform, which enables multi-product and multi-satellite NRT imagery generation using public Worldview web application. The Worldview figure shows that OMI detected a high concentration of SO_2 plume (purple to red) over northern Iraq on October 23, 2016, overlaid on an Aqua/MODIS True Color image from the same day. The plume originated from a fire set at the Al-Mishraq sulfur mine, about 25 miles southeast of Mosul.

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References:

http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=88994

Li, C., N.A. Krotkov, S.A. Carn, Y. Zhang, R.J.D. Spurr, and J. Joiner (2016), New-generation NASA Aura Ozone Monitoring Instrument volcanic SO_2 dataset: Algorithm description, initial results, and continuation with the Suomi-NPP Ozone Mapping and Profiler Suite, *Atmospheric Measurement Techniques Discuss*ions, doi:10.5194/amt-2016-221.

Data Sources:
Aura Ozone Monitoring Instrument (OMI) SO2 standard products are publicly available from the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omso2_v003.shtml
OMI operational SO_2 products, are ingested within three hours into NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) platform, which enables multi-product and multi-satellite near real-time (NRT) imagery generation using the public NASA Worldview web application (https://worldview.earthdata.nasa.gov/) used to produce the image on slide #1.

The Dutch - Finnish built OMI instrument is part of the NASA's EOS Aura satellite payload. The OMI project is managed by KNMI (PI Pieternel Levelt) and the Netherlands Space Agency (NSO).

Technical Description of the Figure:
Aura/OMI Lower tropospheric SO_2 map on October 23, 2016 overlaid on the Aqua/MODIS True Color map of the same day created using NASA's public WorldView web application (http://go.nasa.gov/2fDdO3d). The composite figure shows that OMI detected high concentrations of SO_2 in the sulfur fire plume (purple to red) over northern Iraq on October 23. According to a Washington Post news article on October 23 2016, the toxic SO_2 plume originated from a fire set at the Mishraq sulfur mine, about 25 miles southeast of Mosul. The fire was also reported by BBC News on October 22 (http://www.bbc.com/news/world-middle-east-37738667). Plumes of SO_2 from the fire were first detected on October 21 and have been observed every day until October 26).

Scientific significance, societal relevance, and relationships to future missions: The SO_2 emissions from the fire created serious air quality issues in Iraq, with several deaths attributed to the fumes. Satellite observations of such events are crucial to assess the geographic extent of the air pollution, estimate ground-level concentrations of SO_2, and forecast transport into other regions. Such sulfur fires also produce a relatively pure SO_2 cloud, which is rarely observed in the atmosphere (other anthropogenic and volcanic SO_2 emissions are mixed with a variety of other gases and particles), which could be used to improve understanding of atmospheric sulfur chemistry.